

REMARKS

Claim 1 has been amended to recite that the independent conductive particles are clusters or a plurality of such particles in the conductive film are coarsely distributed at an interface between the two substances having different dielectric constants periodically distributed in the three dimensional space. This is described *inter alia*, at page 4, lines 22-25.

The coarse distribution is a significant feature of the invention for the reasons set forth page 13 at et seq. It can be obtained by controlling the plating parameters of an electroless plating procedure. At a lower plating times, the individual plural protrusions in the form of particles or clusters formed are not connected to each other and therefore exist as being coarsely distributed. The result is that the conductive particles are in the state of a discontinuous metal film which prevents current from being conducted along a relatively long path and provides an advantage equivalent to the case where a metal is coated with an insulation film. Attenuation, band width and band gap increase by forming the conductive film on the unit cell, the frequency at which the band gap appears is decreased and the apparent dielectric constant of the unit cell becomes high. This is equivalent to providing a photonic crystal with a high dielectric constant material. When the plating time is too long, the conductive particles are distributed sequentially and form a continuous film through which current is freely conducted, causing the structure of the two substances having different dielectric constants periodically distributed in the three dimensional space to have no effect, whereby the band gap disappears.

The obviousness type double patent rejection is moot in light of the terminal disclaimer which is being submitted herewith.

It is respectfully submitted that the claims are not anticipated by Kabushiki and the rejection of claims 1-6 and 9-12 under 35 U.S.C. 102 can be withdrawn.

Kabushiki relates to a three dimensional structure which is a porous body having a plurality of regions loaded with a substance to thereby form a photonic band. The loaded material acts as the indispensable steric wiring [00005]. The reference describes making a porous body and then providing a different material in the porous portion by, for example, a plating treatment. If the inner surface of the pore has been chemically modified, a metal or metal oxide can precipitate and grow about the chemically modified portion acting as a catalyst to promote growth. Depending on where the precipitation starts, the precipitated metal can close the pore to inhibit precipitation deep inside the porous body or permit the precipitation to be started from a region deep inside the body [0080]. For example, if a polymer surface is wet with an aqueous solution of copper sulfate and irradiated with a laser, copper atoms are taken into the surface of the polymer and act as a nucleus to permit copper to be selectively precipitated onto the irradiated portion by the electroless plating thereby, forming a three dimensional wiring structure made of copper within the polymeric porous body [0082]. This reference thus discloses forming a continuous conductive film in the pores.

There is no teaching or suggestion in Kabushiki of a conductive film having independent conductive particles or cluster of a plurality of conductive particles coarsely distributed at any interface between the pores and the polymeric structure. An anticipation rejection, therefore, is not tenable. The reference provides no reason that one skilled in the art would ever desire to form a conductive film having independent conductive particles or clusters coarsely distributed at an interface between substances, and therefore, the reference also fails to render the claimed invention obvious.

Claims 1-5, 7-9, 11 and 13 were rejected under 35 U.S.C. 102 over Zakhidov. This rejection is also respectfully traversed.

This reference relates to a templating process in which one three dimensional structure is used as a negative to form another three dimensional structure. For the Examiner's information, an article by Zakhidov and some of his co-inventors (and others) having a figure diagrammatically showing the templating is submitted herewith.

In the described method, a first material A is formed into spheres having three dimensional periodicity with voids between the spheres, the resulting structure is treated to form necks between spheres of material A, a material B is then infiltrated into the spherical structure and finally, material A is removed from the composite structure. The nature of infiltrated material B is not restricted. Also, a number of different infiltrating processes can be used. It can be a surface templating process where a coating layer is formed on the interior surface of the spheres. Alternatively, a volume templating process in which the void volume of the spheres is completely filled can be employed. See, e.g., column 11, lines 64-67. Neither of these processes results in the coarse distribution of the instant invention.

Other templating processes are available. Two of these are patch templating and particle loading. Patch templating is a process in which the surfaces of a void structure are covered with a surface coating of infiltrated material so that no uncoated regions exist (column 12, lines 62-65). The use of gold (to which the Office Action refers) is described in connection with the patch coating process at column 13, lines 1-4. This process also does not result in the coarse distribution of the present invention. In particle loading, particles are infiltrated and aggregated together to form a mechanically robust structure which will

not de-aggregate and be lost when the host material A is extracted. Given the fact that the material B is taking the place of the voids in material A, it will be appreciated that once again, a continuous film is being prepared, albeit by an aggregation process.

In none of the templating processes described is a conductive film having independent conductive particles or clusters of a plurality of conductive particles coarsely distributed therein formed. To the extent there may be conductive particles or clusters, they are continuously distributed so as to form a uniform conductive film. Accordingly, the structure made by Zakhidov is different from that claimed in the present case and an anticipation rejection is not appropriate. Further, Zakhidov provides no reason for forming a conductive film having particles or clusters coarsely distributed at an interface between substances having different dielectric constants periodically distributed in a three dimensional space, and therefore, no rejection is based on obviousness is appropriate.

In view of the above amendment, applicant believes the pending application is in condition for allowance.

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Metal Sphere Photonic Crystals by Nanomolding

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Crystals of nanosize metal spheres have potential applications as diverse as photonics, thermoelectrics, and magnetics.^{1,2} Though methods exist for the chemical synthesis of metal nanospheres³ and the self-assembly of these spheres into submicron thick crystals,¹ the fabrication of large crystals has been illusive. In contrast, centimeter-size face-centered-cubic (fcc) crystals of SiO₂ nanospheres (porous opals) can be routinely fabricated by sphere self-assembly.⁴ Since no methods are available for growing large crystals of metal nanospheres, we have developed a different approach which builds upon recent success^{5–12} in the fabrication of *inverse opals*. Since these inverse opals replicate the void space of ordinary porous SiO₂ opals (Figure 1a), we can use them as nanomolds for “casting” crystals of metal nanospheres. Herein we present two methods based on this strategy for the fabrication of large crystals of metal nanospheres, including NaCl-type crystals based on two different size nanospheres. This NaCl structure was previously obtainable only for metal sphere sizes an order of magnitude smaller than the photonic crystal range.¹³

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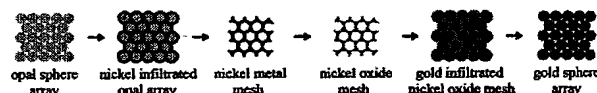
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(a) Electrodeposition method



(b) Melt infiltration method

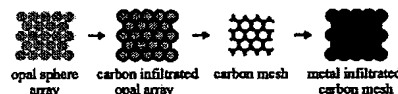


Figure 1. Sequential methods for the preparation of metal nanosphere arrays (a) in a nonconductive matrix and (b) in a conductive carbon matrix.

In the first method (Figure 1a), a sequence of electrochemical and chemical steps was used to prepare metal sphere arrays within a nonconductive matrix. Initially, an fcc porous opal slab containing 290 nm diameter spheres was electrochemically infiltrated¹¹ with nickel. After removal of the opal template with a 2% HF solution, the nickel mesh was slowly oxidized in air at 550 °C for 8 h (Figure 2a). The resulting poorly conducting nickel oxide mesh was then used as a nanomold for the electrochemical growth of a gold nanosphere array. Finally, the NiO template was removed in dilute sulfuric acid to produce an ~30 μm thick array of gold nanospheres (Figure 2b,c).

In the second approach (Figure 1b), periodic nanosphere arrays were fabricated by the infiltration of molten metals into carbon inverse opals made by the phenolic process⁶ (Figure 2d). This melt infiltration (at close to the melting point and pressures of 1–2 kbar) resulted in nanosphere crystals for elemental metals and semiconductors (Pb, Bi, Sb, and Te) and thermoelectric alloys (Bi–Sb, Bi–Te, and Bi–Te–Se). A typical SEM image of a fracture surface (Figure 2e) for centimeter dimension sample shows that the melt-infiltration results in a high-fidelity inverse replica of the carbon matrix, which is itself a high-fidelity inverse replica of the original SiO₂ opal or coats only the internal surfaces.⁶ In this latter case, the void space in the carbon replica comprises two separate labyrinths (percolated spherical voids and a percolated network of octahedral and tetrahedral void spaces). SEM measurements (Figure 2f) show that both of these labyrinths can be filled by melt infiltration at kilobar pressure to make the nanosphere version of a NaCl-type structure.

Since these metal sphere arrays are metallodielectric photonic crystals, new properties should arise which are absent for dielectric photonic crystals—like the plasmon gap observed in the microwave or infrared^{14,15} for metal meshes. These fabrication methods are applicable to various metals, semiconductors, and insulators,¹⁶ and can be used to make nanocomposites. By melt infiltrating an antimony inverse opal (made by infiltrating antimony into a SiO₂ opal, and extracting the SiO₂) with bismuth, we obtained a

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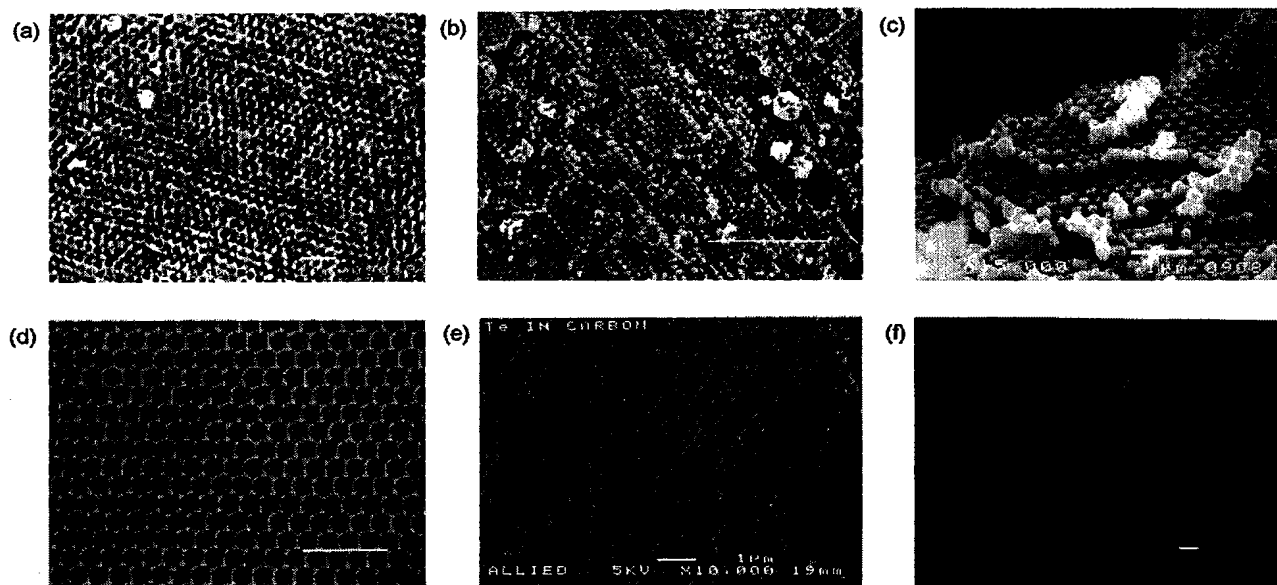


Figure 2. (a) SEM of nickel oxide template used in electrochemical nanomolding, (d) fracture-surface image of a fcc phenolic inverse opal, which in the carbonized state is used as a template for nanomolding by the melt process, (b, c, e, f) fracture-surface SEM images of fcc sphere arrays made by replicating the void space of a porous SiO_2 opal and then replicating the void space of the resulting replica. In panels b and c, arrays of gold spheres were made using two electrochemical replication processes. In panels e and f, sphere arrays were made by replicating the void space of a carbon inverse opal by melt infiltration of tellurium (e) and bismuth (f). In panel f, large metal spheres occupy the corners of the unit cell face (indicated by the square) and smaller metal spheres occupy (or fractionally occupy) the sites between the large spheres, as in the NaCl structure. Stacking faults on close-packed planes in the original SiO_2 opal are replicated in the fabricated sphere arrays, bringing (100) and (111) planes into near coincidence in panels b and e. The length scales are $1\ \mu\text{m}$ except for panels b and f, which are $5\ \mu\text{m}$ and $100\ \text{nm}$, respectively.

thermoelectric “hyper alloy” in which a fcc array of Bi spheres are in an antimony matrix. By applying similar methods to optimally selected thermoelectrics and to combinations of hard

and soft ferromagnets, it may be possible to engineer high-efficiency thermoelectrics and magnets with high-energy storage capabilities.

(16) Note Added in Proof: (a) In November 2000, a similar approach was used for the preparation of ordered hollow titania spheres. see: Rengarajan, R.; Jiang, P.; Colvin, V.; Mittleman, D. *Appl. Phys. Lett.* **2000**, *77*, 3517–3519. (b) Analogous electrochemical strategies have been used for the preparation of one-dimensional porous membranes, see: Hoyer, P.; Masuda, H. *J. Mater. Sci. Lett.* **1996**, *15*, 1228–1230.

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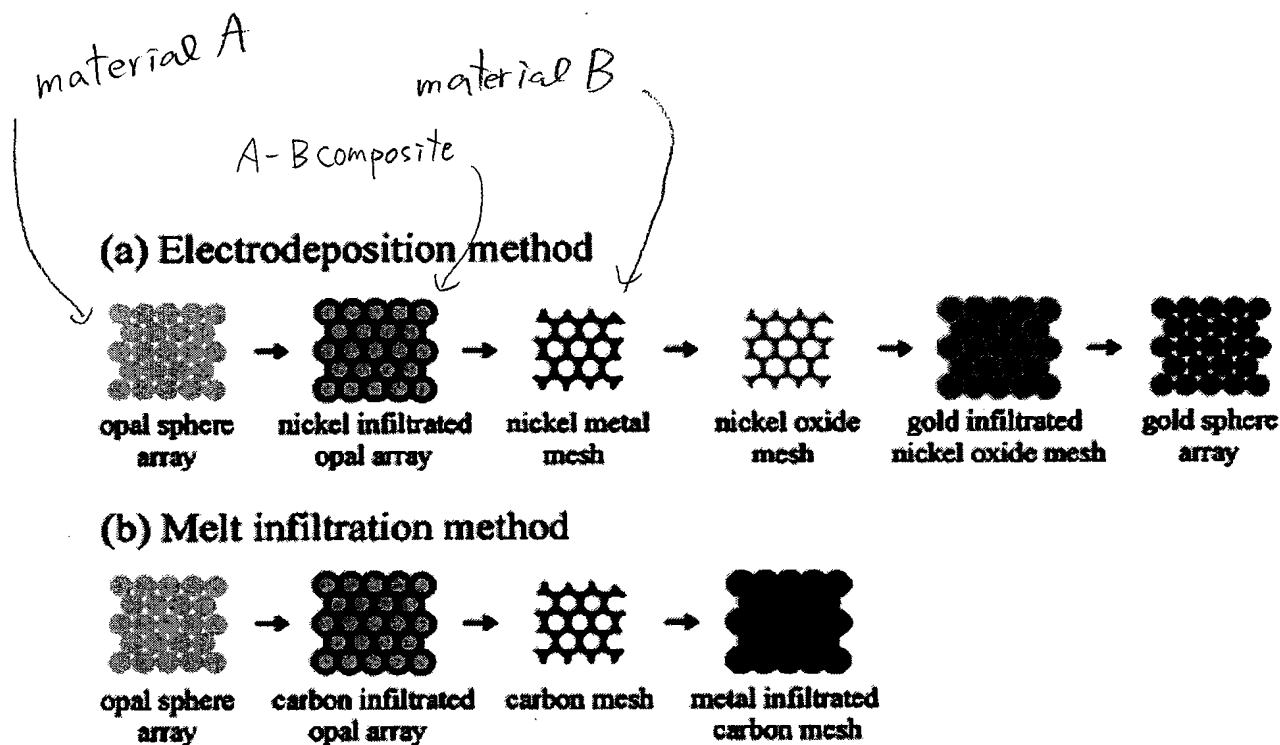


Figure 1. Sequential methods for the preparation of metal nano-sphere arrays (a) in a nonconductive matrix and (b) in a conductive carbon matrix.